

#### **IV.C.4 Development, Characterization and Evaluation of Transition Metal/Chalcogen-Based Cathode Catalysts for PEM Fuel Cells**

*Stephen Campbell*

*Ballard Power Systems*

*9000 Glenlyon Parkway*

*Burnaby, BC, CANADA V5J 5J9*

*Phone: (604) 412-3151; Fax: (604) 412-4704; E-mail: [stephen.campbell@ballard.com](mailto:stephen.campbell@ballard.com)*

*DOE Technology Development Manager: Donna Ho*

*Phone: (202) 586-8000; Fax: (202) 586-9811; E-mail: [Donna.Ho@ee.doe.gov](mailto:Donna.Ho@ee.doe.gov)*

*Subcontractors:*

*University of British Columbia, Vancouver, BC*

*Case Western Reserve University, Cleveland, OH*

#### **Objectives**

To develop a non-precious metal cathode catalyst for proton exchange membrane (PEM) fuel cells which is as active and as durable as current platinum group metal-based catalysts at a significantly reduced cost.

- Develop non-precious metal cathode catalyst composition and structure.
- Develop process which may be scaled up to produce dispersed catalyst with same structure and composition.
- Evaluate performance and stability and demonstrate both in a short stack.

#### **Technical Barriers**

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Stack Material and Manufacturing Cost
- Durability

#### **Approach**

- Determine the optimum catalyst composition and structure using well-defined, thin film materials on glassy carbon.
- Best metal, best chalcogen and ratio
- Best structure/phase of that composition
- Duplicate this structure to the extent possible dispersed on a carbon black support using a process amenable to manufacturing.
- Optimize the electrode structure in a fuel cell (catalyst loading and ionomer/ catalyst interface) and demonstrate performance and durability.

#### **Accomplishments**

- Design of rotating disc electrode with removable glassy carbon (GC) disc for sputter coating and ultrahigh vacuum (UHV) characterization completed.
- Sputter coater commissioned. Initial calibration underway using Co and Se targets.

- Procedures for electrochemical and UHV characterization being developed using these  $\text{Co}_x\text{Se}_y$  films.
- Baseline Pt films for comparison have been prepared.
- Project remains on track and within budget.

### **Future Directions**

- Complete initial screening matrix (Co, Cr, Fe, & Se, S) by 10/04 and downselect system for detailed optimization.
- Complete detailed optimization and characterization by 6/05.
- Develop process to make dispersed catalyst on carbon support by 6/06.
- Optimize catalyst layer structure in membrane electrode assembly by 11/06.
- Assess stability and performance in short stack by 6/07.
- Deliver stack for independent evaluation (6/07).

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### **Introduction**

Since the first demonstration of the fuel cell electrochemistry in 1839, platinum has been used as the electrode material of choice because it enhances, or catalyzes, the oxygen reduction reaction on the cathode so that the chemistry may be used as a practical power source. Commercialization of this technology has been hampered by the prohibitive cost and availability of platinum. Cheaper alternatives have been found for use in alkali fuel cells; the same metals work well in acid fuel cells but also dissolve readily, making the lifetime of the product very short. Recently, efforts have been renewed to find a stable alternative, or rather to find a way to stabilize the cheaper metals and, if possible, raise the open circuit voltage close to that provided by platinum.

In the past few years, an effective catalyst has been demonstrated which uses ruthenium in close association with added selenium [1,2]. The catalyst appears to be almost as active as platinum and more stable than ruthenium metal alone. Unfortunately, ruthenium is a precious metal and does not qualify as a cheap alternative to platinum, but the approach of adding chalcogens to a metal to impart activity and stability has some merit and is worth pursuing. Literature attempts to develop catalysts rarely start with fundamentals, and all too quickly dispersed materials are tested in fuel cells for performance and stability without any really effective analysis and characterization of the materials in question. This project takes a different approach.

### **Approach**

The initial screening matrix of metals and chalcogens is deposited on a well-defined glassy carbon surface in a thin film which may be well characterized with regard to composition, structure and electrochemical activity and stability. In this way, the most promising material may be further optimized in structure to provide a target structure to be attained in a dispersed, supported catalyst. This catalyst will then be manufactured using a scalable, aqueous/thermal process to produce lab-scale quantities of material as close as possible to the structure and composition determined by the thin film study.

This catalyst will then be evaluated in fuel cells at Ballard. This will involve optimization of the catalyst loading on the carbon support, the electrode catalyst loading and the ionomer content, optimizing for both performance and stability. The final demonstration will be a short stack which will be run to fulfill the deliverables of performance and stability.

### **Results**

This project is in the early stages. The sputter coater for the thin films has been commissioned, and the screening matrix has been started using Co and Se as the first materials. The electrochemical system has been set up with the removable GC disc designed and operating. Sputtered platinum baselines will be established shortly.

**Conclusions**

Thin films may be sputtered onto GC substrates with variable Co/Se ratios. These films adhere well to the substrate.

**References**

1. N. Alonso-Vante, H. Tributsch; *Nature (London)* 323 (1986) 431
2. N. Alonso-Vante, H. Tributsch, O. Solorza-Feria; *Electrochim. Acta* 40 (1995) 567